MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2017/2018

ETM4146 – DIGITAL WIRELESS COMMUNICATIONS

(TE)

21 OCTOBER 2017
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT:

1. This exam paper consists of **5 pages** with **4 questions.**
2. Attempt **ALL questions**. All questions have equal weightage and the breakdown of marks within each question is given.
3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

Question 1

The block diagram of a typical digital wireless communication system is shown in Figure 1.

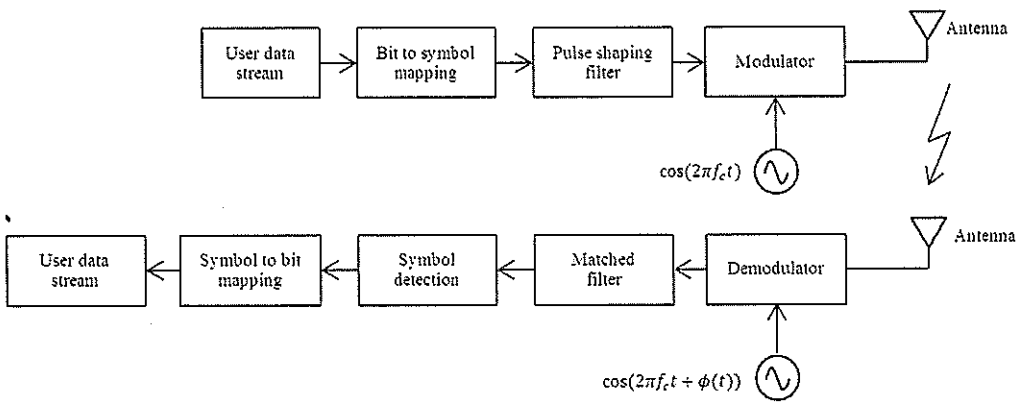

Figure 1

a) Describe the purposes of the following blocks:

i. pulse shaping filter [4 marks]

ii. matched filter [4 marks]

b) If the transmit pulse-shaping filter is selected as the root raised cosine filter with impulse response $g_{tx}(t)$. Determine the impulse response of the matched filter $g_{rx}(t)$. [4 marks]

c) Suppose the modulation scheme is 16-QAM, design (by drawing the block diagram) the required quadrature modulator. Label your diagram properly. [5 marks]

d) The constellation diagram of the 16-QAM modulation is shown in Figure 2.

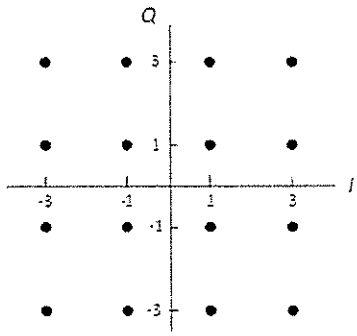

Figure 2

i. Determine the proper scaling for the signal points so that the average power of the modulated signal equals one. Assume all signal points are equally probable. [4 marks]

ii. Label the binary sequence for each signal point according to the Gray coding principle. [4 marks]

Continued...

Question 2

A ternary communication system uses three equiprobable signals of duration T seconds for transmitting data. The received signal is

$$r(t) = As(t) + n(t)$$

where $A \in \{-1, 0, 1\}$, $s(t)$ is the carrier waveform, and $n(t)$ is white Gaussian noise with mean $E[n(t)] = 0$ and covariance $E[n(t_1)n(t_2)] = \sigma^2\delta(t_2 - t_1)$. The optimum receiver computes the correlation metric

$$U = \int_0^T r(t)s(t)dt$$

and compares U with two thresholds 0.5 and -0.5. The decision rules are given as follows:

$$\hat{A} = \begin{cases} 1 & U > 0.5 \\ 0 & -0.5 < U < 0.5 \\ -1 & U < -0.5 \end{cases}$$

a) Suppose $\int_0^T [s(t)]^2 dt = 1$ and $N = \int_0^T n(t)s(t)dt$, where N is a Gaussian random variable. Find the mean and variance of N. [10 marks]

b) Determine the three conditional probabilities of error below:

$$P(error|1\ was\ sent)$$

$$P(error|-1\ was\ sent)$$

$$P(error|0\ was\ sent)$$

Hint: Express the answer using the Q-function $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-a^2/2} da$

[12 marks]

c) Determine the average probability of error, assuming that the three symbols have equal probability to be transmitted. [3 marks]

Continued...

Question 3

The block diagram for a general OFDM receiver is given in Figure 3.

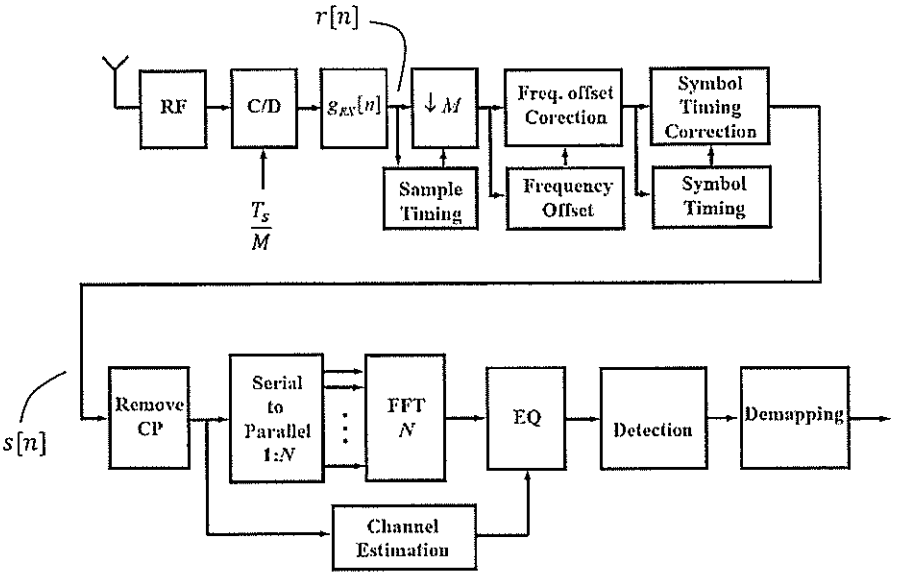

Figure 3

a) The received signal experiences an unknown delay. Suppose upsampling factor $M = 4$ and two data symbols ($P = 2$) are used for sample timing recovery and the following outputs of the matched filter have been observed:

n	0	1	2	3	4	5	6	7
$r[n]$	0.97	1.21	1.01	0.42	-0.35	-0.92	-1.01	-0.58

Perform sample synchronization by direct maximization of the output energy.

[9 marks]

b) Suppose FFT length $N = 4$ and cyclic prefix of length 2 are considered for the OFDM receiver in Figure 3 and the current received OFDM symbol (before removing CP) is given in the table below:

n	0	1	2	3	4	5
$s[n]$	0.25+j0.25	0.5+j0.5	0.25+j0.25	0.5-j0.5	0.25-j0.25	0.5+j0.5

The frequency response of the channel is given by $H[k]$ ={1.5, 1-j0.5, 0.5, 1+j0.5}. Apply frequency-domain equalization to recover the transmitted data symbols.

Hint: $e^{j\theta} = \cos\theta + j\sin\theta$

[16 marks]

Continued...

Question 4

a) Explain the differences between receive diversity and spatial multiplexing.

[12 marks]

b) Consider a deterministic SIMO channel with AWGN in which the elements of the channel vector $\boldsymbol{h} = [h_1, h_2, \ldots, h_{N_R}]$ satisfy the conditions $|h_i|^2 = 1$, for $i = 1, 2, \ldots, N_R$.

i. Determine the capacity of this SIMO channel when $\boldsymbol{h}$ is known at the receiver only. [7 marks]

ii. Suppose that $\boldsymbol{h}$ is also known at the transmitter. Does this additional knowledge increase the channel capacity? Explain. [6 marks]

End of paper.